Atmospheric Profiles, Clouds and the Evolution of Sea Ice Cover in the Beaufort and Chukchi Seas

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Award Number: N00014-12-1-0234
http://recuv.colorado.edu

LONG-TERM GOALS

This is a collaborative research project with the University of Washington (Axel Schweiger, PI). Its purpose is to examine the role of sea-ice and cloud interactions in the retreat of the seasonal ice zone (SIZ). As sea ice retreats further, changes in lower atmospheric temperature, humidity, winds, and clouds are likely to result from changed sea ice concentrations and ocean temperatures. These changes in turn will affect the evolution of the SIZ. An appropriate representation of this feedback loop in models is critical if we want to advance prediction skill in the SIZ. The overall project is an integrated observation and modeling program aimed at understanding the interplay of atmosphere, ice, and ocean in the SIZ of the Beaufort and Chukchi seas (BCSIZ). It will take advantage of routine Coast Guard C-130 domain awareness missions that take place at two-weekly intervals from March through November.

This portion of the overall project will contribute to technology development by adapting and deploying a new generation of truly expendable (<$700) micro-aerial vehicles (Data Hawk and SmartSonde) designed to obtain detailed high-vertical-resolution temperature, humidity and wind profiles and cloud layering information that cannot be obtained with traditional dropsondes. Our vision is that these vehicles will deliver new, inexpensive measurement capabilities for research and operational purposes in the data sparse region of the BCSIZ as well as other regions of the globe. This project provides a unique and cost-effective opportunity to establish a fully integrated observation and modeling program that builds on existing experience and data in a region that is poorly understood and is undergoing rapid change. Improved prediction of the marine environment in this area may be critical for future Navy operations.

OBJECTIVES

The main objective of the University of Colorado portion of the project is to adapt an existing low cost, expendable small unmanned aircraft system (sUAS) called the DataHawk for air-deployment from a Coast Guard C-130 to measure temperature and humidity profiles and cloud top and base heights in the seasonal ice zone.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2012	**N/A**	**-**

4. TITLE AND SUBTITLE
Atmospheric Profiles, Clouds and the Evolution of Sea Ice Cover in the Beaufort and Chukchi Seas

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Aerospace Engineering Sciences University of Colorado Boulder, CO 80309

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

APPROACH

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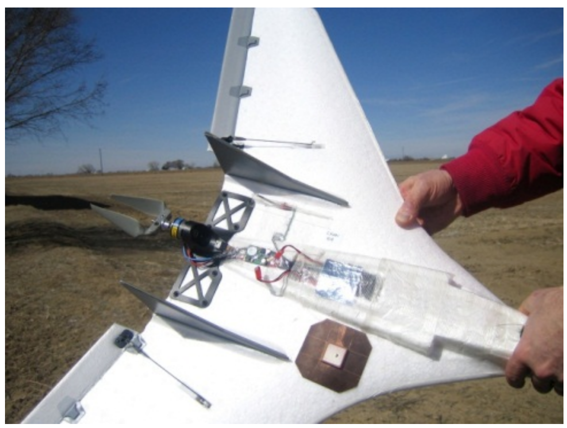
The approach builds on an existing low cost capability to measure in-situ atmospheric data, consisting of a small unmanned aircraft system (DataHawk) developed at the University of Colorado. The Data Hawk (Figure at right) is an electrically powered miniature UAV equipped with a thermodynamic sensor package measuring pressure, temperature, humidity, turbulence, and mean winds. The Data Hawk type of vehicle occupies a niche in between a drop or balloon sonde, which is low cost but cannot be guided, and a typical UAV, which provides guidance flexibility but uses costly avionics and commercial aerospace components. The Data Hawk vehicle and its avionics were designed with low cost and atmospheric sensing applications in mind. It uses a custom autopilot (Figure 5), developed by the investigators [*Pisano et al.,* 2007], using aerodynamics and control principles to minimize the flight control complexity, significantly reducing the size and cost of electronics and sensor components. It takes advantage of low cost components for the airframe and electric propulsion (from high-volume manufacturing for the radio control hobby industry). The flight control utilizes newly developed, robust, vector field guidance strategies [*Lawrence et al.*, 2008] to automate flight and simplify the ground station interface so that pilot training is not necessary to operate the vehicle. Currently, this vehicle and the flight control system are produced in small quantities at a unit cost of $700, more than an order of magnitude lower than other UAVs with similar capabilities, such as the folding wing BAE Coyote.



The sensing and avionics system on the DataHawk will be adapted to a folding-wing airframe that can be deployed from a Coast Guard C-130. This new vehicle, called the SmartSonde, will be expendible, similar to a dropsonde, but can be guided to regions of interest and can remain aloft, climbing and desceding, for approximately 1 hour to obtain high-resolution atmospheric measurements. This work will be carried out at the University of Colorado by a graduate student in Aerospace Engineering Sciences, under the direction of PI Dale Lawrence.

WORK COMPLETED

Although the project was awarded in January of 2012, authority to spend at the University of Colorado was not available until March, 2012. Hence a student could not hired until June, 2012 (starting in the Summer term). Accomplishments toward the tasks outlined in the project proposal are detailed below.

- **Task 4: Develop, integrate and test long range transmission using the DataHawk.**
This task has not been addressed yet, other than some background research into various options. This work is scheduled for the last quarter of 2012 and the first quarter of 2013. Previous work on another project evaluated newly available radio hardware that is compatible with the long-range, low data rate needs of this application. It was found that local oscillator stability was poor, limiting the signal-to-noise improvements possible by narrowing the modulation bandwidth. Options for longer range data communications going forward are as follows:
    - Temperature control the SmartSonde radio hardware to reduce oscillator drift.
    - Increase transmission power using a RF power amplifier on the SmartSonde
    - Utilize a high gain antenna on the ground station
    - Design an asymmetric radio system, where the ground station can track oscillator drift with additional electronics, enabling the use of existing low cost radio hardware on the SmartSonde.
    - Utilize the radio hardware on commercial drop sondes, e.g. with the manufacturer's assistance (in support of a wider product applications base).
- **Task 5: Design a tube launch canister and release mechanism for the SmartSonde.**
This has been the focus of the work so far. An update of the previous SmartSonde design that can fit into an A-size sonobuoy canister has been developed, constructed, and test flown. It still requires some re-design work to improve ruggedness and flight stability. This should be completed by the second quarter of 2013. The pictures below show the prototype in the folded and deployed configurations. This design features a high-aspect-ratio wing for long duration flight, a snap-catch wing latching mechanism that provides a stiff wing structure when latched, but an ability to snap forward during a hard nose landing to avoid breaking the wing spars. This improves the survivability of the vehicle in applications where it could be recovered.

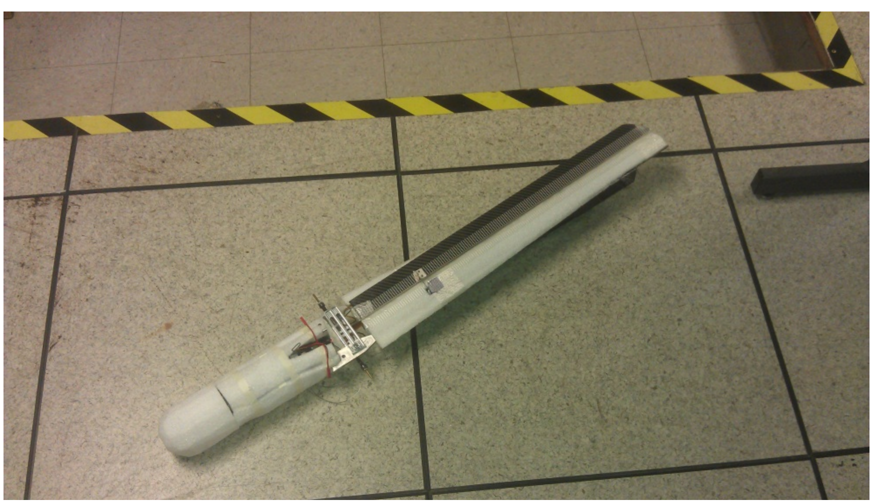


Figure 1: Updated SmartSonde design compatible with deployment from an A-size sonobuoy tube (4in diameter, 36in long), showing the folded wing configuration.

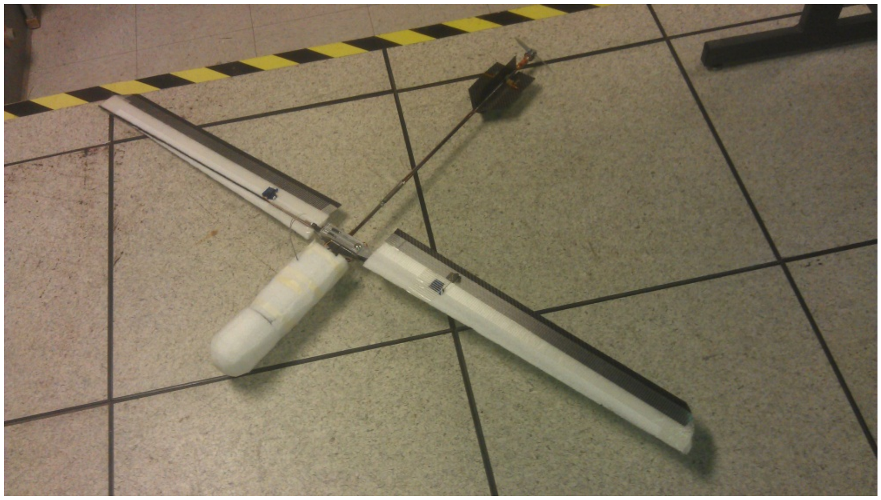


Figure 2: Updated SmartSonde design showing the deployed wing configuration.

RESULTS

Through design and flight testing of the new folding wing SmartSonde, we learned:

- A compact wing folding/latching mechanism can be practical using an offset wing approach. This enables the wings to fold over each other and to have a chord approximately equal to the diameter of the launch tube, providing a low wing loading and high aspect ratio needed for slow, long duration flight suited to this sensing application.
- Initial wind spar designs were not rugged enough.These were re-designed to reduce stress concentrations where the spar exits the folding mechanism to prevent spar breakage upon landing.
- Initial tail motor and propeller choices designed to fit into the launch tube diameter without folding did not provide adequate thrust. There were re-designed to use a larger motor and folding propeller, increasing the thrust yet maintaining the ability to launch from the A-size sonobuoy tube.

IMPACT/APPLICATIONS

The new SmartSonde folding wing design enables the slow flying sUAS to be deployed in a variety of ways from much higher speed delivery vehicles, including 1) sonobuoy tube ejection, 2) hand dropping from the rear ramp (e.g. for the C-130), 3) release from wing pods, and 4) release from fuselage stores pods or bays. It also enables ground or water launch from bungee or air gun launchers. This provides a flexible ability to deliver the sensing system from a variety of carriers, expanding the ability to take atmospheric measurements at low cost over wide areas.

RELATED PROJECTS

The Marginal Ice Zone Process Experiment (MIZOPEX) seeks to explore the use of unmanned aircraft systems (UAS) to provide a complementary ability to make surface and sub-surface measurements in the Arctic marginal ice zone. The DataHawk vehicles that were precursors to the SmartSonde in this project are being re-purposed in MIZOPEX as one-way self-deploying surface sondes (SDSS) to land in the ocean in and near the ice margins to measure surface and subsurface sea temperatures over a ten day period. See http://ccar.colorado.edu/mizopex/index.html for more information.

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[Lawrence et al, 2008] D. A. Lawrence, E. W. Frew, and W. J. Pisano, ``Lyapunov Vector Fields for Autonomous UAV Flight Control'', *AIAA J. Guidance, Control, and Dynamics*, Vol. 31, No. 5, pp. 1220--1229, 2008.

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